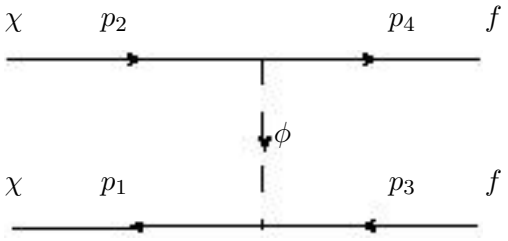
Cross-sections

1 Two Interaction Lagrangians

a) Consider the following interaction lagrangian between dark matter fermion χ, a scalar field ϕ and some other fermion f

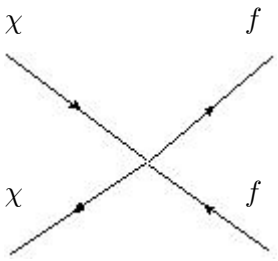
$$\mathcal{L} \supset \lambda\, \phi \bar{f} \chi + \text{h.c.}.$$

Assuming that $m_f = 0$ compute the averaged and spin-summed (amplitude)^2 for the following diagram in the limit $m_\phi^2 \gg m_\chi^2$:



b) Next consider the following dimension six interaction Lagrangian (such a Lagrangian arises when a massive intermediate vector boson is integrated out, for example):

$$\mathcal{L} \supset \frac{1}{\Lambda^2} \bar{\chi} \gamma^\mu \gamma^5 \chi\, \bar{f} \gamma_\mu f.$$



Again, assuming that $m_f = 0$ compute the (amplitude)^2 for the above diagram.

Useful Formulae:

Apart from the Feynman rules you may find the following identities useful:

- $$\sum_s u_s(p)\bar{u}_s(p) = \not{p} + m$$
$$\sum_s v_s(p)\bar{v}_s(p) = \not{p} - m$$

- $$\begin{aligned} \mathrm{Tr}\gamma^\mu\gamma^\nu &= 4\eta^{\mu\nu} \\ \mathrm{Tr}\gamma^\mu\gamma^\nu\gamma^\lambda\gamma^\rho &= 4\left(\eta^{\mu\nu}\eta^{\lambda\rho} + \eta^{\mu\rho}\eta^{\nu\lambda} - \eta^{\mu\lambda}\eta^{\nu\rho}\right) \\ \mathrm{Tr}\gamma^\mu\gamma^\nu\gamma^\rho &= 0 \end{aligned}$$